AUDIO AMPLIFIER FOR A TELEVISION RECEIVER

By Samuel A. Schwartz

I. INTRODUCTION

The required audio output power of the audio amplifier of conventional home entertainment television receivers ranges from 1/2 watt for small portable sets up to 2-1/2 watts for larger sets. The 1-watt amplifier to be discussed was used in the experimental receiver that was built and is suitable for 19-inch portable receivers.

The audio amplifier consists of a driver stage and an output stage both operating Class-A. One watt of output power is the maximum practical level of Class-A operation that can be obtained from the particular type of transistor case structure (TO-5) used in the amplifier. For higher power outputs, Class-AB operation with two output transistors is recommended. A single stage driver is also adequate for this mode of operation.

The signal source for the audio amplifier is a Foster-Seeley discriminator located physically on the 4.5 mc intercarrier amplifier. The average output level from the discriminator is 100 mV at an impedance level of 1 kilohm. The required power gain from the discriminator input to the speaker terminals is 50 db. An additional 13 db, built into the amplifier, provides gain reserve to handle unusually low-levels.

II. DESIGN OF AUDIO OUTPUT AMPLIFIER

The design of the output amplifier is based on a graphical construction that adequately defines high level operation. The transistor used in the amplifier is an S5306E which can be operated safely at a dissipation of 3 watts. The graphical construction shown in Fig. 1, contains an area of operation bounded by a curve defining the 3-watt dissipation level. A line is drawn from the point where V_{CC} = 12 V with a slope proportional to the d-c resistance of the primary winding on the output transformer. The intersection of this line with the dissipation curve is the location of the quiescent operating point. The load line, determined for maximum power output, is drawn through the quiescent point intersecting the collector current axis at 530 mA. A line drawn

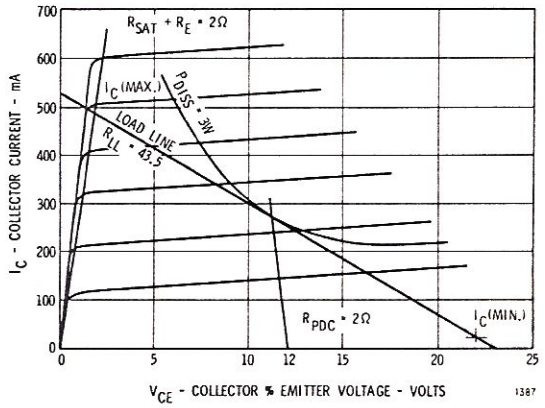

FIG. 1. Construction of load lines.

from the origin, with a slope proportional to V_{CE} (sat) plus the voltage drop across the external emitter resistance, intersects the load line at the maximum collector current limit. The values obtained from the graphical construction for the change in load current and voltage determine the output power as follows:

$$P_L = (\Delta E)(\Delta I) / 8$$
$$= (21)(0.475) / 8 = 1.25 \text{ W} \qquad (1)$$

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The transformed primary load resistance is obtained by subtracting the d-c resistance of the output transformer primary from the optimum value of load line resistance. Therefore solving for this resistance gives

$$R_{LP} = R_{LL} - R_{PDC}$$
$$= 43.5 - 2 = 41.5\ \Omega \qquad (2)$$

The d-c resistance of the transformer secondary winding can be added to the speaker load resistance as shown in Fig. 2, to give the total secondary resistance so that the transformer ratio can be calculated, hence

$$n = \sqrt{\frac{R_{LP}}{R_{SP} + R_{SDC}}} = \sqrt{\frac{41.5}{3.2 + .5}} = 3.35 \qquad (3)$$

The output transformer must be designed to handle a d-c current of 265 mA. This requires an air-gapped core structure that is typical of Class-A output transformers.

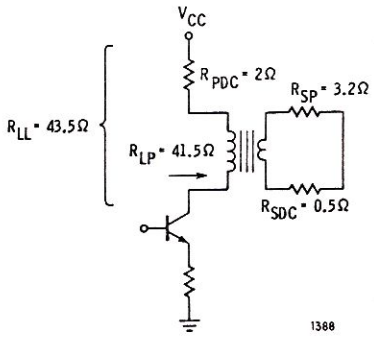

FIG. 2. Load circuit of audio amplifier.

The actual power delivered to the speaker is found as shown below:

$$P_{SP} = P_L \left(\frac{R_{LP}}{R_{LL}}\right)\left(\frac{R_{SP}}{R_{SP} + R_{SDC}}\right)$$
$$P_{SP} = 1.25 \left(\frac{41.5}{43.5}\right)\left(\frac{3.2}{3.2 + 0.5}\right)$$
$$= 1.03 \text{ watts} \qquad (4)$$

It is necessary next to calculate the input resistance of the output stage in order to find the power gain. The solution is

$$R_{in} = h_{ie} + (\beta_o + 1) R_E$$
$$= 1 + (40 + 1) = 42\ \Omega \qquad (5)$$

Calculation of the power gain of the audio output stage is shown below:

$$P.G. = \frac{\beta_o^2 R_L}{R_{in}} = \frac{(40)^2 (43.5)}{42}$$
$$= 1660 = 32.2 \text{ db} \qquad (6)$$

The bias network for this stage is designed to provide a collector current of 265 mA while maintaining adequate d-c stability.

III. DESIGN OF AUDIO DRIVER STAGE

The audio driver stage consists of a relatively low-level Class-A amplifier which is transformer coupled to the output stage. The transistor Q_1, used in the driver is a general purpose unit designated the SE6001. By assuming that the driver transformer is 75% efficient, the required output power from the driver stage becomes

$$P_{DR} = \frac{P_L}{(P.G.)(0.75)}$$
$$= \frac{1.25}{(1660)(0.75)} = 1 \text{ mW} \qquad (7)$$

In order to maintain a conservative design, the drive power is doubled to 2 mW to take care of variations in circuit parameters. The load resistance of the driver stage is shown below:

$$R_{L1} = \frac{(\Delta V_{CC})^2}{2P_O} = \frac{(11)^2}{2(2 \times 10^{-3})}$$

$$= 30.25 \text{ K} \qquad (8)$$

The turns ratio of the driver transformer is calculated in the conventional manner

$$n = \sqrt{R_{L1}/R_{in}} = \sqrt{30 \times 10^3/42}$$

$$n = 26.7 \qquad (9)$$

The d-c current is the primary of the driver transformer is given approximately by solving the equation

$$I_{DC} = 2P_O / V_{CE}$$

$$= 2(2 \times 10^{-3})/11 = 0.364 \text{ mA} \qquad (10)$$

The power gain of the driver stage can be reduced from its maximum value by the addition of emitter resistance. As a result, the input impedance is increased, thereby reducing the loss in the discriminator deemphasis network. The input impedance is given approximately by the following expression for a power gain of 30 db:

$$R_{in} = \frac{\beta_o^2 R_L}{P.G.\ (1 + \beta_o R_L h_{ob})} \qquad (11)$$

and substituting values gives the result

$$R_{in} = \frac{(30)^2 (30 \times 10^3)}{10^3 \left[1 + (30)(30 \times 10^3)(0.5 \times 10^{-6})\right]}$$

$$= 18.6 \text{ K ohms}$$

The current gain of the driver[1] is found by solving the following equation:

$$A_I = \frac{\beta_o}{1 + \beta_o R_L h_{ob}}$$

$$= \frac{30}{1 + 30(30 \times 10^3)(5 \times 10^{-6})}$$

$$= 20.7 \qquad (12)$$

The required voltage gain for a power gain of 1000 is shown below:

$$A_V = 1000/20.7 = 48.2 \qquad (13)$$

The external emitter resistance required for gain reduction is

$$R_E = \frac{R_L}{A_V} - \frac{26}{I_e} = \frac{30 \times 10^3}{48.2} - \frac{26}{0.5} = 570\,\Omega \qquad (14)$$

The bias network, shown in Fig. 3, is designed to provide a d-c collector current of 0.5 milliampere while maintaining d-c stability in the driver circuit. The input impedance to the driver is reduced by the bias network to the following value:

$$R_{in} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_{in}}}$$

$$= \frac{1}{\frac{1}{56 \times 10^3} + \frac{1}{5.6 \times 10^3} + \frac{1}{18.6 \times 10^3}}$$

$$R_{in} = 4 \text{ K}\Omega \qquad (15)$$

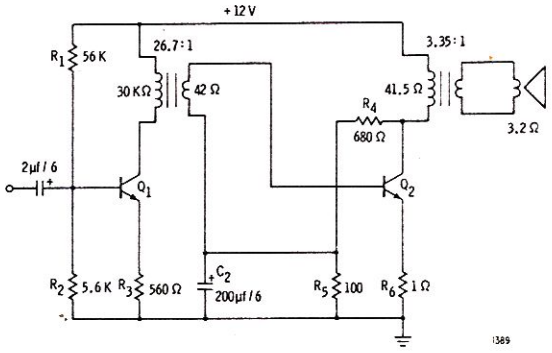

FIG. 3. Schematic diagram of audio amplifier.

The input coupling capacitor C_1 in combination with the input resistance R_{in} provides a low frequency 3 db point at 20 cps. However, the low frequency 3 db point of the overall amplifier is higher than 20 cps due to the low frequency rolloff of the driver and output transformers.

$$C = \frac{1}{\omega_{20} R_{in}} = \frac{1}{2\pi(20)(4 \times 10^3)} = 2\,\mu f \qquad (16)$$

The schematic diagram of the overall amplifier is shown in Fig. 3.

IV. CONCLUSION

The audio amplifier of a television receiver can be constructed using two silicon planar transistors for power outputs up to one watt. Above the one watt level, the use of a push-pull output stage is required thereby necessitating at least three transistors in the complete amplifier. The above configurations provide adequate power gain for operation from conventional f-m discriminators.

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References

1. David Dewitt and Arthur L. Rosoff, "Transistor Electronics, " McGraw-Hill Book Co., 1959.

LIST OF SYMBOLS

A_V	Voltage Gain
C_1	Coupling Capacitance
ΔE	Change in Collector Voltage
h_{ie}	Common-emitter Input Resistance
h_{ob}	Common-base Output Admittance
I_{DC}	D-C Current in Transformer Primary
ΔI	Change in Collector Current
n	Transformer Ratio
P_{DR}	Driver Stage Output Power
P_L	Power Into Load
P_{SP}	Power Into Speaker
P.G.	Power Gain
R_E	Emitter Resistor
R_{in}	Input Resistance of Output Stage
R'_{in}	Input Resistance of Output Stage Including Bias Network
R_{L1}	Load Resistance of Driver
R_{LL}	Resistance of Load Line
R_{LP}	Primary Load Resistance
R_{PDC}	D-C Resistance of Primary Winding
R_{SDC}	D-C Resistance of Secondary Winding
R_{SP}	Speaker Load Resistance
V_{CC}	Collector Supply Voltage
V_{CE}(Sat)	Collector Saturation Voltage
β_o	Forward Current Transfer Ratio at D-C